properly placed for the desired nerve-block procedure. Upon obtaining paresthesia or after entering the proper fascial plane, the tubing is unclamped and aspiration is accomplished by an assistant (or with the anesthetist's free hand) without movement of the needle. The anesthetic is then injected. If the syringe must be detached and re-attached, this may be done without moving the needle, because of the flexibility of the extension tubing. Worthy of mention is the fact that if care is not taken to fill the extension tubing completely with anesthetic agent, several ml of air may be injected during performance of the block. This is not a serious occurrence, assuming the injection is not intravascular.

This "immobile needle" has been used in several hundred nerve blocks and has unquestionably enabled us to avoid many failures or partial blocks, particularly in cases where removal of the syringe proved to be mechanically difficult or awkward.

A Minimally Traumatic, Intermittently Inflated Endotracheal Cuff

JOHN I. LAURIA, M.D., AND MURRAY N. ANDERSEN, M.D.

Recent reports have indicated an increasing awareness of the danger of tracheal stenosis resulting from cuffed tracheostomy or endotracheal tubes employed for long-term ventilatory support.[1, 2, 3] In the majority of instances tracheal stenosis appears to be produced by the pressure of the inflated cuff rather than by the tube itself. Despite various attempts to reduce the incidence of this complication, efforts to date have failed to provide a definitive solution to the problem.[4]

It is generally believed that pressure against the tracheal mucosa by the inflated cuff, particularly during periods of hypotension and reduced blood flow, interferes with circulation to the mucosa and underlying soft tissues, resulting in pressure necrosis. The objective of the present study was to devise a simple, functionally-reliable technique which would reduce cuff pressure effects to the lowest level possible. The rationale upon which the method reported is based assumes that such pressure effects would be minimized by: 1) intracuff pressure which is at the lowest level adequate to prevent air leak during the inspiratory phase; 2) reduction of duration of cuff inflation time to a minimum, *i.e.*, inflation during the inspiratory phase only; 3) configuration of the inflated cuff such that deformation of the trachea by the cuff would not be required to produce an adequate air seal.

These requirements appear to have been met by the development of an automatically-inflated cuff system in which intracuff pressure is equal to, and synchronous with, intratracheal pressure (the absolute minimum required to avoid leakage) and whose use requires no additional mechanisms other than a direct connection to the inspiratory air flow delivered by the ventilator. The system's essential features are: 1) a cuff large enough to be inflated sufficiently to produce an adequate air seal without stretching the cuff material; 2) inflation of the cuff by the ventilator airway pressure so that intratracheal and intracuff pressures are equal and the cuff inflation period is synchronous with the inspiratory phase of the ventilator. The latter feature is achieved by connecting the cuff-inflating tubing to a side arm of the ventilator connection to the endotracheal tube (fig. 1).

METHODS

The prototype tubes were constructed with a thin-walled Sanders cuff from which the original inflating tubing was removed and replaced with a firmer, more kink-resistant Air-Lon catheter. Both medium and large cuffs

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were used to determine optimum cuff-to-tube and cuff-to-trachea size relationships. The cuffs were cemented to standard endotracheal and tracheostomy tubes with rubber cement, using somewhat undersized tubes in relation to tracheal size so that the tubes themselves would not prevent leakage. Performance characteristics of these cuffed tubes were compared with those of conventional double-walled AirLon cuffs on similar endotracheal and tracheostomy tubes.

To determine the amount of pressure used to inflate the cuff in routine fashion, intracuff pressures were measured in 20 randomly-selected patients under general anesthesia with controlled ventilation, with endotracheal tubes already in place and the cuffs inflated by an anesthesiologist in the standard manner. These included tubes with both Sanders and AirLon cuffs. Cuff pressures were measured through a catheter cemented into the cuff lumen and connected to a strain gauge. Endotracheal pressures were measured by a catheter inserted into the endotracheal tube. Pressures were recorded photographically.

To study the functional characteristics of the automatically-inflated cuff a model trachea was constructed of a plastic tube with an internal diameter of 2.0 cm connected to a lung model, of variable compliance, made of two 20-liter glass bottles. Effectiveness of the air seal obtained with the automatically-inflated cuffs was determined by measuring inspiratory and expiratory minute volumes with Wright spirometers. This method was employed in both the model system and in studies in patients. A pressure-limited Bird Mark VII ventilator and a volume-limited Bennett BA5 ventilator were used to determine the performance with ventilators.

The function of the automatically-inflated cuffs was studied in five patients undergoing general anesthesia with controlled ventilation and in six patients requiring ventilatory support via a cuffed tracheostomy tube. Number 6 AirLon tracheostomy tubes were employed with two types of cuff. One tube was fitted with a large Sanders cuff, which resulted in a substantial redundancy in the amount of cuff; in the other tube, a medium Sanders cuff which had much less redundant material was used. Each tube was tested with both a pressure-limited and a volume-limited ventilator. To simulate a low-compliance situation in a patient, constricting pressure was applied to the chest until the ventilation pressure of the volume-limited ventilator increased above 40 mm Hg.

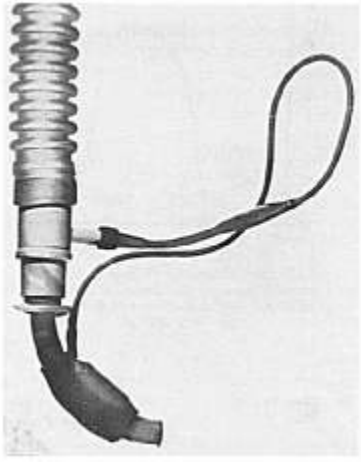

FIG. 1. Prototype assembly showing the oversized cuff mounted on a standard tracheostomy tube. The inflation tube is connected directly to the side-arm of the ventilator attachment.

RESULTS

Cuff inflation pressures measured in the randomly-selected intubated surgical patients ranged from 15 to 40 cm H_2O in single-walled Sanders cuffs and from 75 to 150 mm Hg in double-walled AirLon cuffs. In each case it was believed by the anesthesiologist that the optimum sizes of tube and cuff were being employed, with the cuffs inflated only sufficiently to prevent air leakage.

Studies with the intermittently-inflatable cuff in the model trachea demonstrated that the cuff inflated synchronously with the inspiratory cycle of the ventilator. Intracuff and airway pressures measured during the ventilatory cycle showed them to be essentially identical in magnitude and configuration

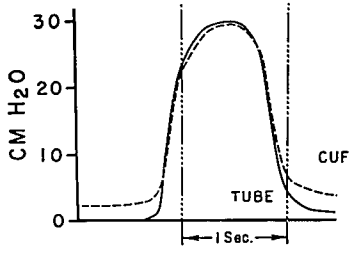

FIG. 2. Simultaneous recording of inspiratory–expiratory pressure in the lumen of an endotracheal tube and in the cuff.

during the inspiratory phase (fig. 2). Intracuff pressure remained slightly above zero during the expiratory phase, a desirable relationship.

The air leakage in the model system using a medium Sanders cuff varied from 10 to 20 per cent of minute volume with an airway pressure of 20 mm Hg; using a large Sanders cuff there was no measurable leakage. Reducing the compliance of the model system resulted in the need for higher airway pressure, to as much as 40 mm Hg. Intracuff pressure again rose synchronously with airway pressure and effective ventilation was produced using one intermittently-inflated cuff, with less than 10 per cent leakage. In five anesthetized patients in whom leakage was measured, it varied from 0 to 10 per cent with the intermittently-inflated large Sanders cuff.

In the unconscious patients with tracheostomies, with the large Sanders cuff the pressure-limited ventilator was cycled by the patient's inspiratory effort, resulting in effective assisted ventilation. The ventilator could not be cycled when a standard AirLon cuff was employed, uninflated, and cycling was inconsistent with the medium Sanders cuff uninflated. Use of the large cuff also resulted in an effective air seal with no detectable leak with either the pressure-limited or the volume-limited ventilator with inflation pressures of 20 to 30 mm Hg. Constriction of the chest to simulate decreased compliance resulted in airway pressures above 40 mm Hg during use of the volume-limited ventilator. Even then, less than 10 per cent leakage resulted.

DISCUSSION

It must be recognized that various factors such as humidity, oxygen toxicity, infection, and blood flow to the mucous membrane undoubtedly play roles in the development of tracheal damage. The pressure of the cuff, however, must be considered a most significant factor. The method of cuff inflation described appears to add a useful simple means of prevention of complications of prolonged intubation and ventilation, while permitting the alternative of use of the cuff in a conventional manner.

The concept of intermittent inflation of the cuff is an obvious approach toward reducing the time element in pressure effects. The double-cuffed tube, with alternate inflation of one or the other cuff, represented one approach to this objective, as does the technique of deflating the cuff intermittently to allow temporary restoration of mucosal circulation. Such methods have the obvious disadvantages of requiring continuous attention and reducing the inflation period only partially.

In 1943 MacIntosh and Mushin[5] described an intermittently-inflated cuff with inflation produced by air pressure from within the lumen of the endotracheal tube communicating with the cuff through side holes in the tube. We considered this approach in a preliminary stage of these studies but believed this method would be less satisfactory because of potential malfunction resulting from obstruction of the side holes by accumulations within the tube and also because such an arrangement would not permit continuous inflation of the cuff in a conventional manner if desired. In addition to the principal objective of reducing the likelihood of pressure necrosis, the system described has the advantage of permitting use in a conventional manner simply by inflating the cuff with a syringe and clamping the inflation tube in the usual way.

A major advantage of the oversized cuff results from its ability to come into contact with the tracheal mucosa circumferentially without stretching the cuff material. With the smaller cuff, the elastic recoil tends to result in a circular configuration when inflated, thereby producing deformation of the trachea, particularly the posterior wall. The intracuff pres-

sures we recorded in such cuffs provides convincing evidence of the high pressures which may be exerted against the tracheal mucosa.

Any method of intermittent inflation of the cuff has the potential disadvantage of permitting aspiration during the period which the cuff is deflated. However, since aspiration is a serious threat only under certain circumstances (*i.e.*, distended stomach, bleeding, etc.), this potential complication should be readily avoidable by the exercise of judgment as to when intermittent inflation may be used safely. When necessary, the cuff may be left inflated in a conventional manner. It is also possible to avoid the hazard of aspiration and to produce a continuous air seal with the same system by adding a small one-way valve to the inflation tube. With this arrangement the cuff will be inflated only to the maximum inspiratory airway pressure, the minimum necessary for an air seal, at the same time insuring that the pressure will be maintained continuously by allowing each inspiratory pressure thrust to be transmitted to the cuff.

Although the present arrangement appears to satisfy our theoretical concepts of a minimally traumatic cuff, further evidence is necessary to demonstrate whether such an arrangement is actually less damaging than constant inflation. Experimental studies to elucidate this point are in progress.

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CASE REPORT

Acute Epiglottitis Managed with Nebulized Epinephrine Delivered by IPPB

Gerald F. McNally, M.D., and Paul H. Lorhan, M.D.

Epiglottitis in a young child represents a fulminating medical emergency. In the United States, acute epiglottitis occurs in approximately one case in every 1,000 pediatric hospital admissions.[1] This condition is seen mostly in children between one and six years of age, but cases in adults have been reported.[2] The incidence is highest in the spring but equal in the two sexes.[3]

The symptoms of acute epiglottitis begin abruptly and include a severe sore throat, dysphagia, drooling, hoarseness, stridor, and dyspnea. The patients appear very ill. The inflamed, edematous epiglottis has been likened to a bright red cherry sitting at the base of the tongue. A vigorous attempt to see the epiglottis is contraindicated, however, since depression of the tongue may cause sudden cessation of respiration.[4] Because the inflamed epiglottis is many times its normal size and, especially with the patient recumbent, it will fall posteriorly across the glottis and obstruct the airway. Poole and Altman have suggested a lateral "airway" roentgenogram instead of repeated examinations of the epiglottis to differentiate between epiglottitis and the subglottic edema of laryngotracheobronchitis.[5]

Treatment in the past has consisted of increased humidification and oxygenation of the inspired gases, administration of steroids, and

Received from the Department of Anesthesiology, Harbor General Hospital, Torrance, California, and the Division of Anesthesiology, University of California Medical Center, Los Angeles, California.